Karlsruhe Institute of Technology

Technology for
Pervasive Computing

A Novel Micro-Vibration Sensor for Activity Recognition: Potential and Limitations

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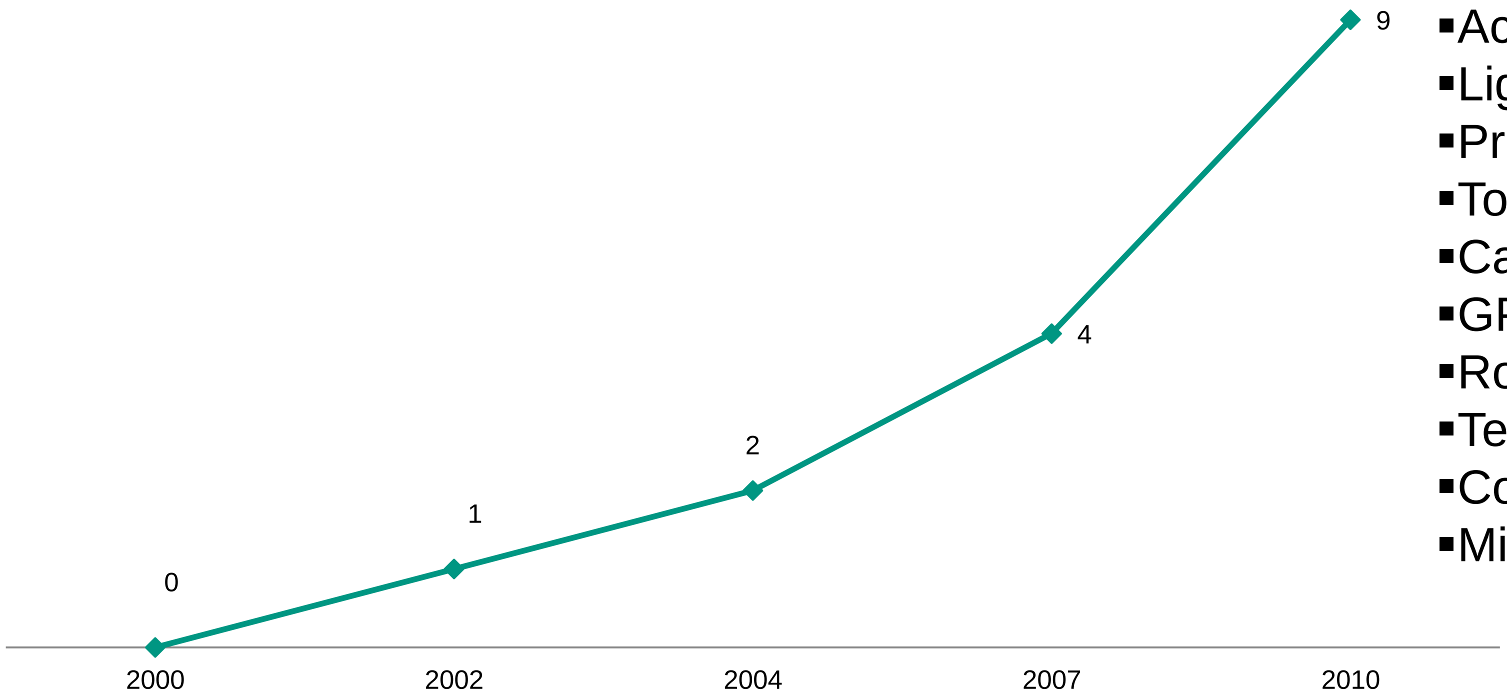
Sensor Modalities on Mobile Phones

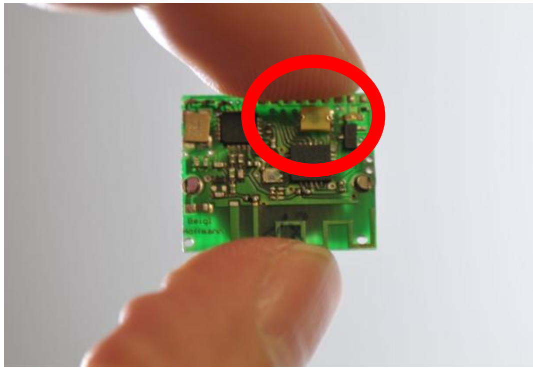


- Acceleration
- Light
- Proximity
- Touch
- Camera
- GPS
- Rotation
- Temperature
- Compass
- Microphone

- How does the community know which sensor is next best thing, and how to use it?

A Novel Sensor

- Recent advances in production techniques improve sensitivity
  - Sensolute GmbH
    www.sensolute.com

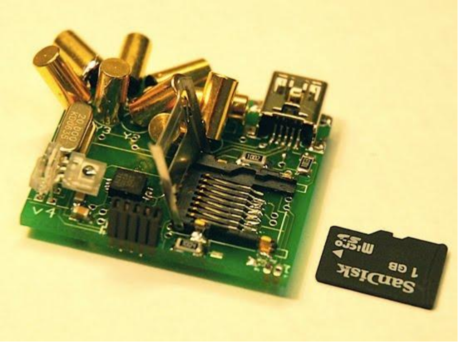


- Devices have become sensitive and stabile
- Asks the question, what can we do with this that we couldn't before?
  - How does it compare with an acceleration sensor for activity recognition?

Technology for Pervasive Computing

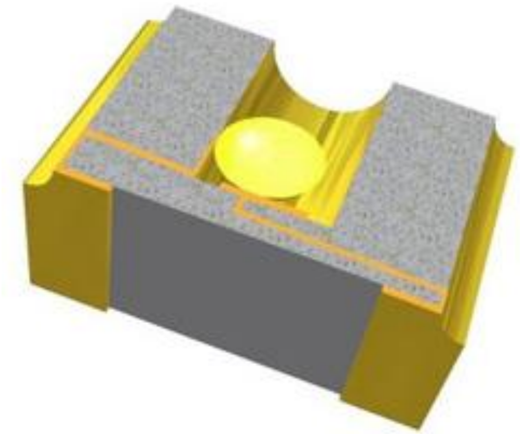
Ball Switch Research

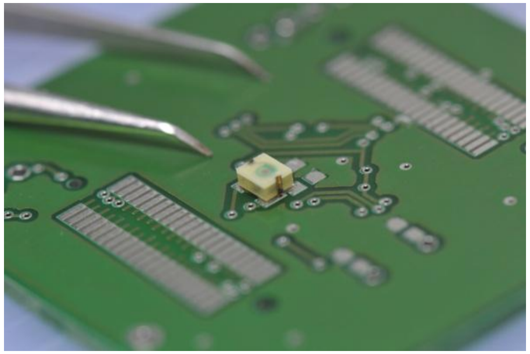
- **“The MediaCup: Awareness Technology embedded in an Everyday Object”** Gellersen, Beigl, Krull, 1999
- “**Spine versus porcupine: a study in distributed wearable activity recognition**” Van Laerhoven, Gellersen, 2004
- “**Using rhythm awareness in long-term activity recognition”** Van Laerhoven, Killian, Schiele, 2008



Micro-vibration sensor

- MVS 0608.02
- 2.45 x 2.85 x 1.7 mm
- Ball diameter of 0.8 mm
- Opens and closes a circuit
- Hermetically sealed chamber
- SMD – automatically mountable and solderable
- Cost: 1.75 USD



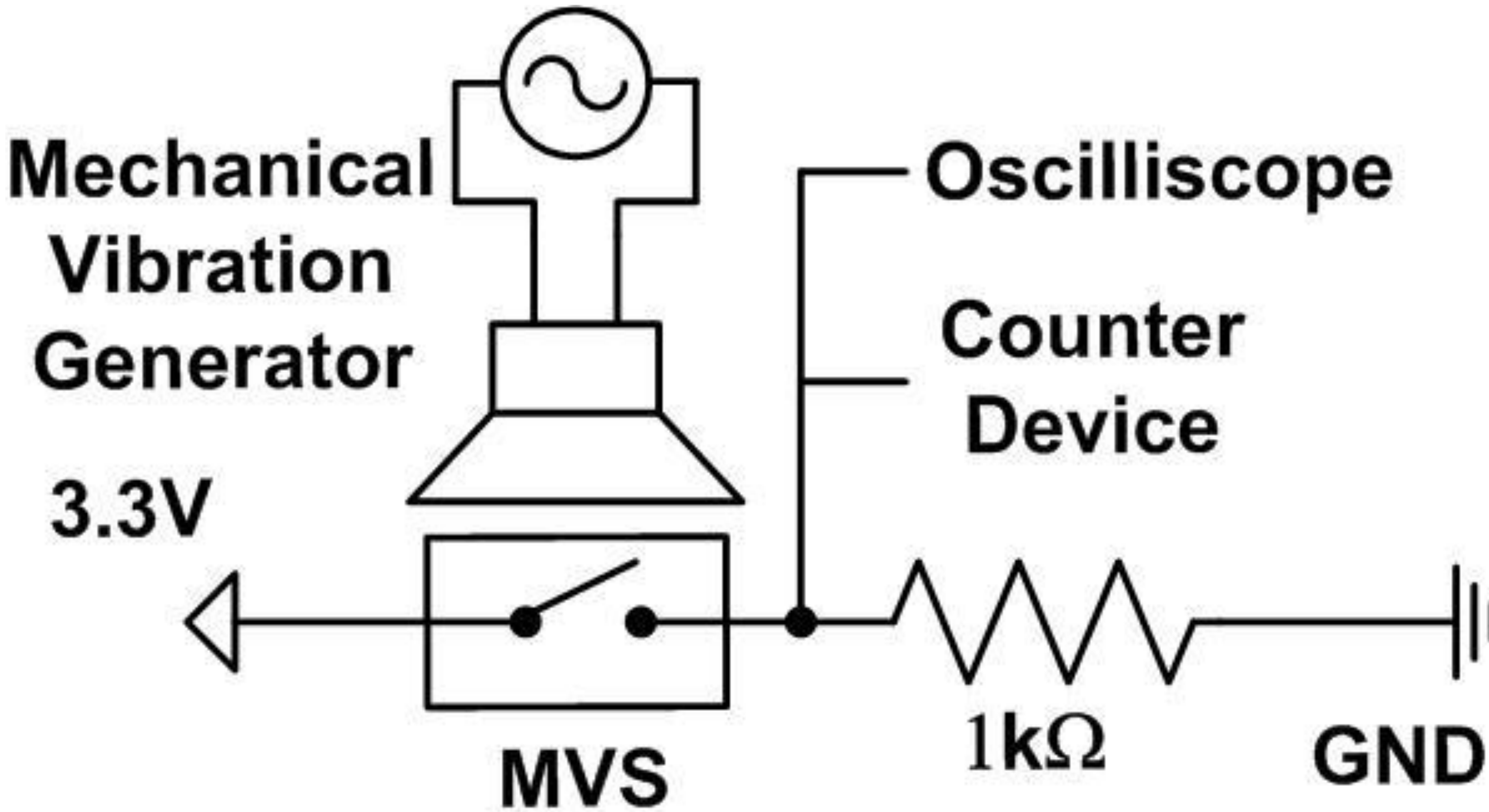


The Data stream

- Digital output signal from MVS
- Interesting units are the unary signal transitions: “events”
- Events summed over short windows to produce the amplitude of a cumulative wave
- This signal “comparable” to analog sensor output
- Sample windows can now be generated using a sliding or overlapping window

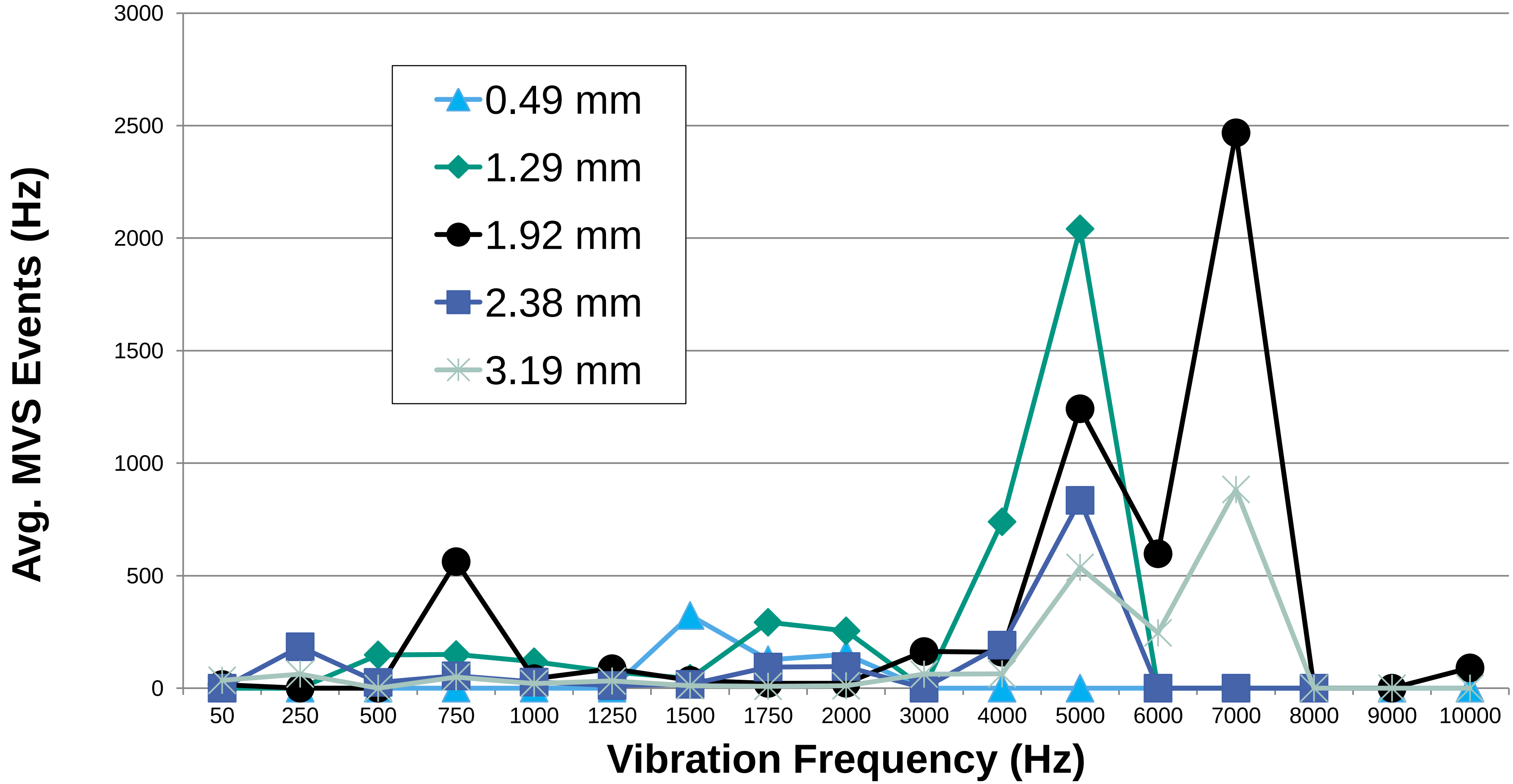
1) MVS Output:

Vibration Analysis



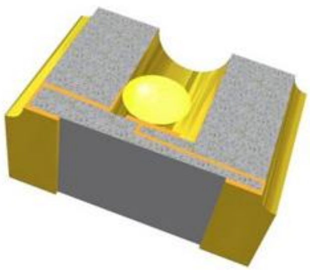
- 50 Hz to 10 kHz
- 1 V to 5 V

Vibration Analysis Results



Constant forced vibration vs ***impulse***

Vibration vs. Acceleration sensor



Micro-vibration sensor

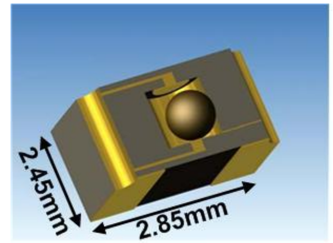
- 1.75 USD
- 2.45 mm x 2.85 mm
- 1 resistor
- 1.5 kHz – 8kHz
- 42 µW* @ 3 V

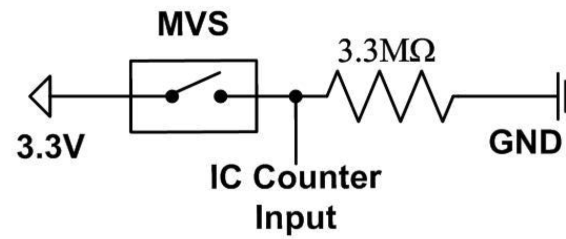
ADXL335 accel. Sensor

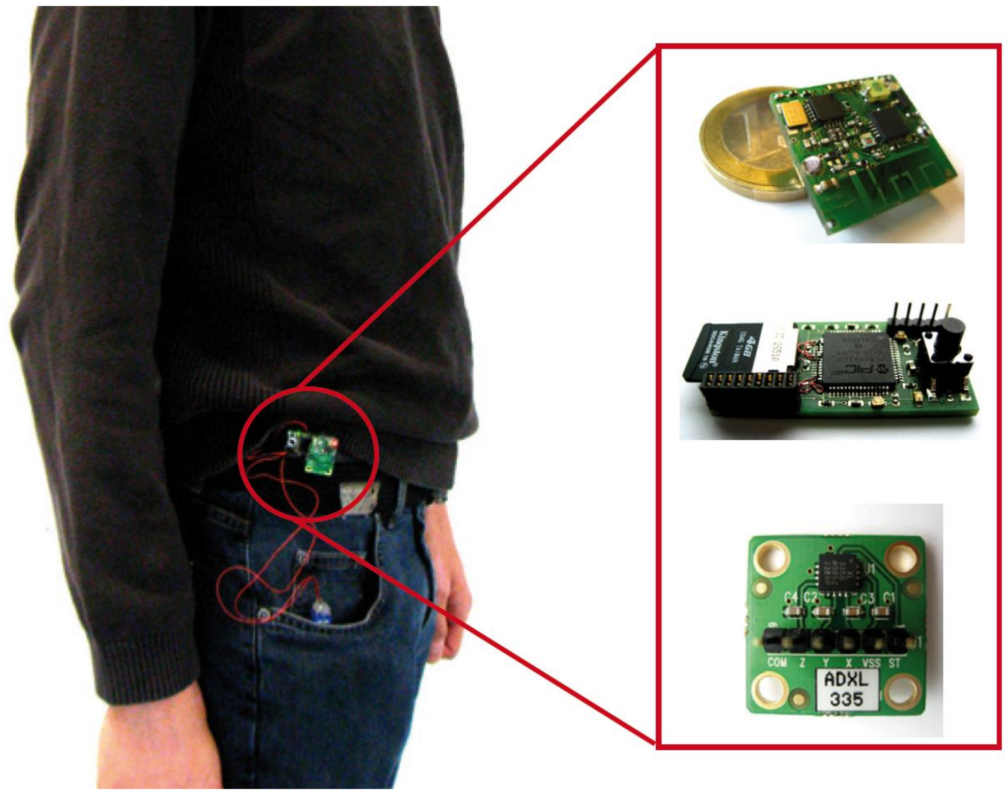
- 5.50 USD
- 4 mm x 4 mm
- 4 capacitors
- .5 Hz – 1.6 kHz
- 2 mW @ 3 V

Activity Recognition: Case Study

- 5 Subjects
- 8 Activities
- 60 Hz sampling
  - Vibration
  - Acceleration
  - Light
  - Temperature
- 142 Minutes of data
- All parameters in paper
- Dataset available at: http://www.teco.edu/~gordon/MVS/







Classification

- 3 classification phases
  - Phase 1: Personalized classification, all subjects, 80%-20%
  - Phase 2: Generalized classification, 4 vs. 1
  - Phase 3: Post-hoc sensing, light temperature acceleration, + MVS
- Classification using WEKA toolkit and three popular classifiers
  - K-Nearest-Neighbors
  - Naïve Bayes
  - C4.5 Decision Tree

3-Phase Results

Phase	Type	IBk	J48	Bayes	Average
No. 1	Personalized MVS	46.2	49.2	34.1	43.2
	Personalized ADXL	91.9	96.6	65.6	84.7
No. 2	Generalized MVS	36.1	34.0	21.4	30.5
	Generalized ADXL	23.0	34.1	53.4	36.8
No. 3	ADXL, Light, Temp.		92.8		
	ADXL, Light, Temp., MVS		96.6		

- ADXL outperformed the MVS
- Recognition drop from personalized to generalized
  - 29.4% for the MVS
  - 56.6% for ADXL
- 4% increase when adding the MVS

Acceleration Results in Detail

a Bus	b Bike	c Walk	d Jog	e Lift	f Type	g Stair	h Stand	
96.9	0.16	0.4	0.1	1.4	0.2	0.5	0.3	a
0.6	99.1	0.0	0.0	0.3	0.0	0.0	0.0	b
0.1	0.1	96.9	0.1	0.8	0.0	0.0	2.0	c
0.1	0.1	0.2	98.8	0.1	0.0	0.0	0.7	d
2.2	0.0	0.3	0.1	92.8	0.1	0.6	4.0	e
0.1	0.1	0.0	0.0	0.1	99.7	0.1	0.1	f
1.2	0.0	0.0	0.0	1.4	0.0	97.3	0.0	g
0.2	0.0	1.3	0.1	5.6	0.1	0.0	92.6	h

- Personalized classification, C4.5 Decision Tree
- Overall 95.6% accuracy
- Standing and riding elevator
- Riding bus and riding elevator
- Generally good results

MVS Results in Detail

a Bus	b Bike	c Walk	d Jog	e Lift	f Type	g Stair	h Stand	
27.1	6.5	3.7	0.4	10.1	40.9	4.5	6.7	a
9.1	49.2	12.5	0.9	5.5	2.5	17.2	3.0	b
2.1	4.7	57.6	8.4	5.9	0.3	20.8	0.2	c
0.6	0.9	9.9	79.1	1.8	0.2	7.3	0.3	d
7.2	3.6	11.3	1.5	26.0	35.6	10.8	4.0	e
2.6	1.5	0.8	0.4	1.4	90.9	0.8	1.5	f
3.5	7.6	21.9	9.8	9.0	0.6	47.1	0.6	g
5.8	2.0	1.0	0.5	5.2	77.8	1.1	6.7	h

- Personalized classification, C4.5 Decision Tree
- Activities which consist of impacts (footfalls, bumps, etc.) are better recognized due to their high frequency components
- Activities with slow or rounded movements have worse recognition rates
- The “Typing” anomaly: high classification rate with many false positives
  - Does not indicate that “typing” is easy to recognize
  - System minimizes error by classifying all sample windows with very little or no activity as typing

Conclusions

- The MVS can be used to sense concussions high-frequency vibrations
- Low cost in terms of size, consumption and price
- Can increase recognition rates in wearable systems
- But, it will not replace the acceleration sensor

That's All

- Thank You!
  - Questions?